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(54) Title: AIR FILTER ASSEMBLY FOR FILTERING AIR HAVING PARTICULATE MATTER

(57) **Abstract:** Air filter assemblies for removing particulate matter from a incoming dirty air stream are provided. The assemblies include a housing having an inlet, an outlet, a dirty air chamber and a clean air chamber and an elongated filter element arranged within the dirty air chamber constructed to remove particulate matter from an incoming air stream. The filter assemblies according to the present invention provide a decreased air flow speed within the dirty air chamber while maintaining air flow volume. Alternately, the filter assemblies according to the present invention provide an increased air flow volume which maintaining air flow speed. The dirty air chamber has side walls, which can be planar or non planar with a distended portion. The filter elements used in the filter assemblies can be cylindrical or non-cylindrical filter elements.

AIR FILTER ASSEMBLY FOR FILTERING AIR HAVING PARTICULATE MATTER

This application is being filed as a PCT International Patent Application in the name of Donaldson Company, Inc., a U.S. national corporation and resident, (Applicant for all countries) on 29 June 2001, designating all countries except US.

Field of the Disclosure

The present disclosure is related to air filtering systems having housings with non-planar side walls.

Background of the Disclosure

Many industries often encounter particulate matter suspended in the atmosphere. In some industries, this particulate matter is a valuable product, for example, starch; it would be beneficial if these suspended particulate could be recovered and reintroduced into the process. For other industries, such as metal or wood working, the particulate matter may be simply dust; it is desirable to remove dust particles from the air in order to provide a clear working environment.

Systems for cleaning an air or other gas stream laden with particulate matter include air filter assemblies that have filter elements disposed in a housing. The filter element may be a bag or sock of a suitable fabric or pleated paper. The gas stream, contaminated with particulate, typically is passed through the housing so that the particulate are captured and retained by the filter element. Cleaning is accomplished by periodically pulsing a brief jet of pressurized air into the interior of the filter element to reverse the air flow through the filter element, causing the collected contaminants to be collected. Such air filter assemblies are disclosed in, for example, U.S. Patent No. 4,218,227 (Frey) and U.S. Patent No. 4,395,269 (Schuler).

Filter elements are usually used in an air filter assembly to process dust particles from an airstream. In a standard design of air filter assembly, an air filter assembly has a clean air chamber and a dirty air chamber. The two chambers are separated by a sheet metal, commonly referred to as a tube sheet. The tube sheet has a number of openings from which filter elements are aligned. The filters

suspend downwardly with or without an angle from the tube sheet openings into the dirty air chamber. Particulate-laden air is introduced into the dirty air chamber, and the particulates collect onto the filter. The filtered air passes through the filters to the interior of the filters, and upwardly out through the openings in the tube sheet into the clean air chamber. From the clean air chamber, the cleaned air is exhausted into the environment, or recirculated for other uses. For example, U.S. Patent Nos. 4,424,070 (Robinson), 4,436,536 (Robinson), 4,443,237 (Ulvestad), 4,445,915 (Robinson), 5,207,812 (Tronto et al.), 4,954,255 (Muller et al.), 5,222,488 (Forsgren), and 5,211,846 (Kott et al.) are prior art examples of prior art cylindrical filter elements of the pleated cartridge type.

Non-cylindrical filter elements are sometimes used to process dust particles from an airstream and provide increased filtration area within a housing than cylindrical filter elements. For example, U.S. Patent No. 5,730,766 (Clements) discloses a non-round unitary filter cartridge having a unitary structure with pleated filter media formed securely about a perforated interior core in a dust collector. U.S. Patent No. 4,661,131 (Howeth) discloses non-cylindrical filters having a greater clean air flow area than a plurality of cylindrical elements fitted within the same dimensional envelope.

In one conventional design of air filter assembly with non-cylindrical filter elements, non-cylindrical filter elements simply replace cylindrical filter elements. With less space between adjacent filter elements, more non-cylindrical filter elements are placed within a housing than cylindrical filter elements. U.S. Patent No. 5,730,766 (Clements) discloses this type of use of non-cylindrical filter elements. In another conventional design of air filter assembly with non-cylindrical filter elements, a plurality of cylindrical elements are replaced by a single non-cylindrical filter element. U.S. Patent No. 4,661,131 (Howeth) discloses this type of use of non-cylindrical filter elements. Unfortunately, each of these conventional designs which utilize non-cylindrical filter elements has its disadvantages and drawbacks.

It has been found that in many conventional systems, an attempt to operate these types of dust collectors at an increased airflow results in increased air velocities, which in turn results in a reduction of filter life. An increased airflow, for

example, 8315 cubic feet per minute (cfm) (about 233 m^3/min) or greater, leads to high cabinet air/dust velocity which results in the dust particulate abrading holes in the filter elements or cartridges. The high cabinet air/dust velocity may also inhibit the drop-out of the dust particles into the collection hopper. This results in the filters being plugged and a loss in total dust collection airflow.

Summary of the Disclosure

The construction and arrangement of the disclosed air filter assemblies helps to overcome the problems of the prior art. In particular, in one embodiment, the structures and arrangements of the assemblies of the present disclosure enable the processing of at least 10% more dust laden air, typically at least 20% more dust laden airflow compared to conventional systems. In preferred systems, the assemblies of the present disclosure result in a dust laden airflow increase greater than 10%, preferably at least 20%, and most preferably at least 25% without a significant change in the overall size of the filter housing apparatus or the number of filter cartridges required. The present design provides this increase either by maintaining the amount of filtration media available for filtering the dirty air, or decreasing the amount of filtration media available, rather than increasing the amount of filtration media. Also, the structure and arrangement of the air filter assembly provides more efficient filter retention/sealing, filter housing apparatus manufacturing, and filter handling.

In another embodiment, the structure and arrangement of the assembly of the present disclosure results in an air velocity that is at least 10%, preferably at least 20%, and most preferably at least 25% less than the air velocity of a similar volume of air being filtered by a conventional air filtration assembly.

In one aspect, the disclosure describes an air filter assembly adapted for removing particulate matter from a high volume air stream.

In one particular embodiment, the present disclosure is directed to an air filter assembly having distended side wall, in particular, an air filter assembly comprising a housing including an air inlet that provides a dirty air volume to the assembly, an air outlet, and a spacer wall separating the housing into a filtering chamber and a clean air chamber. The housing comprises a plurality of side walls

forming the filtering chamber, at least one of the side walls is a non-straight wall, having a first wall portion and a second wall portion. By the term "non-straight", it is meant that the wall is non-planar; that is, the first and second wall portions are positioned with an angle therebetween. A filter construction is positioned in air flow communication with an air flow aperture in the spacer wall, the filter construction including an extension of filter media defining a filter construction inner clean air chamber. Sometimes, a third wall portion is included. Preferably, the housing of the air filter assembly has two opposite facing walls, each side wall having a distended portion formed by the first wall portion and the second wall portion.

In another particular embodiment, the present disclosure is directed to an air filter assembly that uses non-cylindrical filter elements such as oval or elliptical filter element. Such an assembly is capable of handling 25% more air than an air filter assembly utilizing cylindrical filter elements having the same amount, or less, surface area available for filtration. In particular, an air filter assembly of the present disclosure comprises a housing including an air inlet, an air outlet, and a spacer wall separating the housing into a filtering chamber and a clean air chamber, the spacer wall including a first air flow aperture therein. The air inlet provides a dirty air volume to the air filter assembly, where the dirty air volume has an air flow direction. The air filter assembly further includes a first filter construction positioned in air flow communication with the first air flow aperture in the spacer wall; the first filter construction including an extension of filter media disposed between proximal end cap and distal end cap. The filter media, proximal and distal end caps defines a filter construction inner clean air chamber. The first filter construction: is oriented within the filter inner clean air chamber in air flow communication with the spacer wall first air flow aperture; has a cross-sectional area, when taken parallel to the first air flow aperture, the cross-sectional area having a long axis perpendicular to a short axis; and has a width along the long axis and a width along the short axis, the long axis width being greater than the short axis width and the long axis positioned parallel to the air flow direction.

Brief Description of the Drawings

Figure 1A is a perspective view of one type of operational installation of an air filtration system having planar side panels according to the present disclosure;

Figure 1B is a perspective view of another type of operational installation of an air filtration system having distended side panels and non-cylindrical filter elements according to the present disclosure;

Figure 2 is a side elevational view, partially broken away, of one embodiment of the air filtration system of both Figure 1A and 1B utilizing non-cylindrical filter elements;

Figure 3A is a front elevation view of the air filtration system depicted in Figure 1A;

Figure 3B is a front elevation view of the air filtration system depicted in Figure 1B;

Figure 4 is a perspective view of a portion of a mounting arrangement utilized in the air filtration systems of Figures 1A and 1B;

Figure 5A is a top view of a portion of an air filtration system showing a planar side panel for use in the air filtration system of the present disclosure;

Figure 5B is a top view of a portion of an air filtration system showing a distended side panel for use in the air filtration system of the present disclosure;

Figure 6 is a side perspective view of an embodiment of a non-cylindrical element utilized in the air filtration system of the present disclosure;

Figure 7 is an enlarged end view of the non-cylindrical filter element shown in Figure 6;

Figure 8 is an end view of a row of non-cylindrical filter elements mounted in an air filtration system according to the present disclosure; and

Figure 9 is an end view of a row of cylindrical filter elements mounted in an air filtration system.

Detailed Description of the Preferred Embodiment

Referring to Figures 1A and 1B, an air filtration system or assembly is depicted generally at 10 and 10', respectively. The systems 10, 10' depicted are shown with three units or modules configured together in side-by-side arrangement. This arrangement can be, for example, of a size that fits into a 2 meter by 3 meter by 3 meter space (approximately 6 feet by 10 feet by 10 feet).

Each module in Figures 1A and 1B is generally in the shape of a box and includes an upper wall panel 16, and side wall panels 17 or 17'. A front access door 13 and a secondary access door 14 permit access to the interior of each module for purposes of, for example, maintenance. Each module further includes a conduit 11 for receiving dirty or contaminated air (i.e., air with particulate matter therein) into the filter assembly. A like conduit 12 is provided for venting clean or filtered air from the filter assembly 10.

Also shown in Figures 1A and 1B is a motor and chain drive assembly 118 of standard construction for operation of an auger screw in the base portion of the assembly. The auger is used to remove collected particulate from the interior of the air filtration assembly, as will be discussed in detail later.

Referring now to Figure 2, the filter systems are shown in side elevation with one side wall panel 17, 17' being broken away to facilitate description of the arrangement of the various elements of the assembly. In this embodiment, the upper wall panel 16 has an inner wall surface 16' with an air inlet 20 positioned in the upper wall panel 16 so that entering dust-laden air or other contaminated gas is introduced in a downwardly direction (referred to as air flow direction 101) into a dirty air chamber 22. A typical volume of incoming dirty air is about 500 cubic feet per minute (cfm) (about 14 m^3/min) for one cylindrical filter element; in accordance with the present disclosure, a typical volume of incoming dirty air may be at least about 550 cfm (about 15.4 m^3/min), preferably at least about 600 cfm (about 16.8 m^3/min), and more preferably at least about 625 cfm (about 17.5 m^3/min). In many industries where air filter assemblies of this type are installed, the amount of dust or other particulate contaminant in the dirty air stream is about one grain (0.0648 gram) of particulate per each cubic foot of air. Filtered, or "clean air" has less than about 0.001 grain particulate per each cubic foot of air.

The top inlet 20 allows the assembly to utilize the forces of gravity in moving the dust through the assembly 10 to the collection area. The dirty air chamber 22 is defined by the door 13, the upper wall panel 16, two pairs of opposing side wall panels 17, 17' which extend downwardly from the upper panel 16, stepped tube sheet structure 28 (shown in phantom in Figure 2), and a pair of sloping wall surfaces 23, 24. Sloping wall surfaces 23, 24 partially define a collection area or hopper 25 within the base portion of the assembly. The dirty air chamber 22 is a sealed chamber in order to prevent any escape of contaminated air or fluid prior to its being filtered. A bottom base panel or frame 26 is sealed to the side wall panels 17, 17' in any suitable, standard manner. A bottom base panel or frame 26 is sealed to the side wall panels 17, 17' in any suitable, standard manner. The volume of dirty air chamber 22 is generally less than about 176 cubic feet, and is typically about 73 to 121 cubic feet, with one common volume includes about 97 cubic feet.

Side panel 17, 17' is the structure which encloses and encases dirty air chamber 22. Side panel 17, 17' is typically made of, for example, metal or plastic. Top views of side panels 17, 17' are shown in Figures 5A and 5B. In Figure 5A, which corresponds to Figures 1A and 3A, the side panels 17 are planar sheets or walls. When viewed from the exterior of the air filtration system 10, the side panels 17 are two dimensional, i.e., planar or flat. The interior of side panels 17 may include a single stiffener 29 or multiple stiffeners 29, such as rails, bars, and the like, which strengthen the side panels 17. These stiffeners 29 are preferred because the strength inherent in planar side panels 17 themselves is typically ineffective at securely resisting the large volumes of dirty air that pass through dirty air chamber 22. Typically, such stiffeners are placed internally and extend vertically from upper wall panel 16 to bottom panel 26 (not shown in Figure 5A), although horizontal stiffeners may be used in some embodiments.

Still referring to Figure 5A, the distance "a" between filter element 32 and side panel 17 is approximately 10.4 cm (4.1 inches) and the distance "b" between stiffener 29 and filter element 32 is approximately 5.3 cm (2.1 inches).

Figure 5B, which illustrates an alternate embodiment, shows stiffeners 29 and planar side panel of Figure 5A removed and replaced with expanded or distended side panel 17'; distended side panel 17' is a non-straight side

panel or wall. All side panels that form the housing may be designed as distended side panels, or in some instances it may be desired to have two opposite side panels as distended side panels. Side panel 17' is distended from filter elements 32 and includes sloped panel 18 and distended panel 19. Distended panel 19 is displaced a distance "e" out from where a planar side panel 17 (as shown in Figure 5A) would be, thus providing a maximum distance between filter element 32 and distended side panel 17' of "c". Sloped panel 18 is placed at an angle "α" from where a planar side panel 17 would be. As seen in Figure 5B, a portion of side panel 17' may remain parallel to filter element 32 and non-distended. Overall, distended side panel 17' increases the area through which the dirty air can flow down, thereby lowering the velocity of the air traveling past the filter elements 32 and providing for increased volumes of air. By utilizing a distended feature within side panel 17', stiffeners 29 as shown in Figure 5A or other such features are not needed to strengthen the side panel because the shape produced by the angled panels 17' provides the desired stiffness.

Distended side panel 17' includes various wall portions or sections, such as sloped panel 18 and distended panel 19, and may include a parallel wall portion 71. In a preferred embodiment, both parallel wall portion 71 and distended panel 19 are parallel to filter element 32, and sloped panel 18 is positioned at an angle to each of wall portion 71 and distended panel 19. Typically, the angles between wall portion 71 and sloped panel 18 and sloped panel 18 and distended panel 19 are the same.

The distance "a", shown in Figure 5B between filter element 32 and parallel wall portion 71, is at least about 5 cm, less than about 30 cm, typically about 5 to 20 cm, and in one example, about 10 cm, but is usually similar to the distance between side panel 17 and filter element 32 in the planar embodiment shown in Figure 5A. The distance "c", between filter element 32 and distended wall panel 19, is at least about 10 cm, less than about 50 cm, typically about 10 to 25 cm, and in one example about 17 cm. The length "d" of "d'"of wall portion 71, if present, may be less than about 20 cm, typically less than about 10 cm, and in one example, about 8 cm. In some embodiments "d" may be 0 cm (zero). A wall portion 71 may be present on either end or both ends of side panel 17. The amount of distention of side

panel 17' from wall portion 71, "e", is at least about 2 cm, less than about 20 cm, typically about 2 to 15 cm, and in one example about 6 cm. The distention is based on the angle "α" between wall portion 71 and sloped panel 18; this angle is generally greater than about 2 degrees, less than 90 degrees, and typically about 5 to 20 degrees. The actual distance between filter element 32 and various parts of side panel 17' will be largely dependent on the amount of space available for the entire air assembly unit 10. "f", the length of distended panel 19, is generally dependent on the total length of side panel 17', on the length of filter element(s) 32, and on the length of wall portion 71 and sloped portion 18. The length of "f" is generally less than about 150 cm, typically about 10 to 100 cm, and in one example about 65 cm. In some embodiments, no distended panel 19, having length "f" is present; rather, two sloped portions 18 meet, providing a triangular distended area.

The distances between filter element 32 and any portion of distended side wall 17' (for example, "a'" between filter element 32 and wall portion 71, and "c" between filter element 32 and distended portion 19) should be measured so that a minimum distance measurement is achieved. For example, the measurement should be taken perpendicular to filter element 32, rather than at an angle, so that the shortest distance is measured.

In one embodiment, the distance "a" between filter element 32 and the end of side panel 17' is approximately 10.4 cm (4.1 inches), similar to that distance in the planar embodiment shown in Figure 5A. In a particular preferred embodiment utilizing the side panel 17' of the present disclosure, "a" is 10.4 cm (4.1 inches), "c" is 16.7 cm (6.6 inches), "d" is 8.6 cm (3.4 inches), "e" is 6.4 cm (2.5 inches), "f", the length of distended panel 19, is 66.0 cm (26.0 inches), and angle "α" is about 14.2 degrees. These dimensions are preferred for a filter element 32 having a maximum width (when measured perpendicular to its length) of about 38 cm (about 15 inches) and a length of 132.1 cm (52.0 inches). In another preferred embodiment, "a" is 11.0 cm (4.3 inches), "c" is 17.3 cm (6.8 inches), "d" is 8.6 cm (3.4 inches), and "e", "f", and angle "α" are the same. The filter element 32 may in fact be two stacked filter elements 32 each having a length of about 66 cm (about 26 inches).

The distended side panel provides for increased volume within the housing, and in particular within dirty air chamber 22, compared to a planar housing without the distended side panel. An increased dirty air chamber volume allows for processing of increased volumes of dirty air, compared to dirty air chambers without the distended side panel; preferably the air filter assembly of the present disclosure, with a non-planar, distended side panel, provides for increases in air volume of at least 10%, preferably at least 20%, and most preferably at least 25%. The increased dirty air chamber volume also provides for decreased velocity of the dirty air as it circulates throughout dirty air chamber 22, compared to the velocity of dirty air in a planar sided dirty air chamber. A slower air velocity prolongs the filter element life by decreasing the abrasion caused by the particulate contaminants impacting on the filter element. Preferably, by utilizing a non-planar, distended side panel according to the present disclosure, air velocity is decreased by at least 10%, preferably by at least 20%, and most preferably at least 25%.

The particular shape, size, and style of distended side panel 17' can be controlled by the space available for location of air filtration assembly 10'. It is desired to minimize the floor space needed for assembly 10'; however, it is preferable to increase the area of dirty air chamber 22. In some air filtration assembly designs, it may be desired to design side wall panel 17' to have a long, yet thin, distended panel 19 (i.e., long "f" and short "c"), or a short but thick panel 19 (i.e., short "f" and long "c"), or even multiple distended panels 19. In some instances it may be preferred to taper or slope the top or bottom portion of distended panel 19; see for example, Figure 3. Distended panel 19 may or may not be centered within side panel 17', either vertically or horizontally. Further, distended panel 19, sloped panel 18, and other features of side panel 17' may vary along the height or width of side panel 17'.

Referring now again to the overall assembly 10, 10', sealed to a structural frame member 27 along each of the side wall panels 17, 17' is mounted a spacer wall or tube sheet structure 28 to which are mounted the separate filter elements 32 of the assembly. The tube sheet structure 28 is sealed on all four of its sides to hermetically seal the dirty air chamber 22 from a clean air chamber 60. The volume of clean air chamber 60 is generally less than about 35 cubic feet (about 1

m^3), and is typically about 19 to 35 cubic feet (about 0.5 to 1 m^3). One common volume is 34.9 cubic feet (about 1 m^3). Together with the dirty air chamber 32, this provides a total chamber volume of about 92 to 211 cubic feet (about 2.6 to about 6 m^3).

In the embodiment shown, spacer wall or tube sheet structure 28 has a step-like design, although it is understood that planar tube sheet structures, or structures having other geometries, can be used. The structure 28 in the shown embodiment has three steps or indented portions. Each step portion includes an upwardly extending back member 30 and a leg member 31 extending at right angles from the back member 30. The tube sheet structure 28 is preferably constructed from a single piece of sheet steel and thus, the individual step portions are continuous extensions of the step portion immediately above it and below it.

As shown in Figures 2, 3A and 3B, the filter elements 32 mounted to the structure 28 are positioned in the dirty air chamber 22 in stepped, partially overlapping relationship. The filter elements 32 may be positioned in a generally downward direction at an acute angle of inclination with respect to the horizontal plane of the upper surface panel 16. In this manner, a distribution space 33 is defined in the uppermost portion of the filter assembly 10 by an inclined baffle 50, the side wall panels 17, 17', the upper wall panel inner surface 16', and front access door 13. The inclined baffle 50 is positioned to dissipate the incoming air flow throughout the dirty air chamber 22. As the dirty air enters the assembly 10 from the inlet 20, it is received into the distribution space 33 prior to its being filtered.

Dust particles are removed from the dirty air by filter elements 32. The individual filter elements 32 typically comprises a pleated filtration media 35 extending essentially the length of filter element 32 and an outer liner 36 that protects the filtration media 35 from physical damages. Likewise, an inner liner 34 is positioned inside the filtration media 35 to protect and support filtration media 35. Each end of the pleated media typically has an end cap thereon. The filter elements 32 used with filter assemblies 10, 10' of the present invention may be cylindrical or non-cylindrical. Additional details regarding non-cylindrical filter elements are provided below. Additionally, details of construction of non-cylindrical filter elements 32 are disclosed in U.S. Patent No. 4,171,963 (Schuler).

Each of the ends of the filtration media 35 is preferably potted or confined in an end cap (or collar member). A first end cap 82, referred to herein as the "proximal end", is an annular end cap and allows access to the interior of filter element 32. The opposite "distal end cap" 44 is a continuous cap that seals access to the interior of filtration media 35. The filtration media 35 and end caps 82, 44 define a filtered or clean air chamber (not shown). In some embodiments, such as when two filter elements 32 are stacked axially, distal end cap 44 of the first element 32 may be an annular cap, in order to allow air to flow freely between the internal chambers of the two stacked elements.

Generally, the portion of the media 35 covered by the end caps is not considered porous to air as it is shielded by the end cap. When mounted on structure 28 via yoke 36, proximal end cap 82 is positioned against structure 28. In some embodiments, a gasket may be disposed between the proximal end cap 82 and the structure 28. By pressing the filter element 32 toward the structure 28 and compressing the gasket, an axially directed seal is provided between proximal end cap 82 and sheet structure 28 to prevent air leakage.

An example of how a filter element 32, cylindrical or non-cylindrical, may be supported to the sheet structure 28 is disclosed in U.S. Patent Nos. 4,395,269 and 5,562,746. In particular, the support assembly for supporting the filter element is shown in Figure 4. Back member portion 30 of the structure 28 has an opening (not shown) through which is disposed a Venturi element 70 (shown in phantom in Figure 2). Venturi element 70 is positioned on the tube sheet structure 28 in relation to the filter element 32 such that the Venturi 70 is disposed in the clean air chamber 60. A yoke assembly 36, constructed to extended through the Venturi element 70 and into the center of filter element 32, is used for supporting the filter element 32. The yoke assembly 36 includes steel rods attached to (for example, by welding) and extending from the structure 28. Yoke assembly 36 is positioned to extend from structure 28 into the dirty air chamber 22. Alternatively, although not shown in the figures, steel rods of the yoke assembly can be threaded at the proximal end and extend through notches in the Venturi bell-mouthed-portion and apertures in the flange of the Venturi element 70. In such a case, a rod can be structured so that it can be secured to the tube sheet structure 28 together with the flange of the Venturi

element 70 by a nut placed on the clean air chamber side of the tube sheet structure. This can be achieved in a variety of ways. For example, the rod can have an integral ridge proximate its proximal end to act as a stop as the proximal end of the rod is extended through an aperture of the tube sheet structure 28 to be fastened with a nut. This arrangement has the advantage that no rod extends through the throat of the Venturi element 70. Another practicable alternative for securing the filter element to the tube sheet structure 28 is one similar to the arrangement disclosed in U.S. Patent No. 4,218,227 (Frey).

In the embodiment shown in Figure 4, each yoke assembly 36 is secured essentially perpendicular to the structure 28 so as to suspend the filter elements 32 at an acute angle with respect to horizontal. (Back member 30, on which yoke assembly 36 is positioned, is at an angle to horizontal). In some embodiments, however, back member 30 may be vertical, i.e., perpendicular to horizontal, and yoke assembly 36 is structured so that filter elements 32 are nevertheless positioned at an acute angle with respect to horizontal. The preferred range for the angle of inclination of the filter elements 32 is about 15°-30° from the horizontal, although the system can work with any angle of inclination, including no angle. In the embodiment shown in Figures 2, 3A and 3B, each back member 30 of the structure 28 has two horizontally spaced apart yoke assemblies 36 mounted thereon. Preferably, all of the filter elements 32 on structure 28 are parallel to one another.

Figure 2 illustrates the placement of a pair of filter elements 32 onto each yoke assembly 36; two filter elements 32 are positioned axially in relation to one another. An annular distal end cap 44 having a centrally located opening is aligned with the end plate 39 so as to sealingly cover the outboard end of the second filter element of each pair. This allows the removable attachment of a clamping arrangement for axially compressing the gaskets (not shown in Figures 2-3) of the filter elements 32 to seal them to the tube sheet structure 28 as well as to each other. Also, a fastening bolt 46 with its special handle 47 is inserted through aligned apertures in the end plate 39 and end cap 44 to secure the two together.

Directly behind the tube sheet structure 28 is the clean air chamber 60 which is defined by the back surface panel 62 of the assembly and a portion of the

upper surface panel 16, a portion of the two opposing side panels 17, 17', and the back side of the stepped tube sheet structure 28. Mounted in the back surface panel 62 is a clean air outlet 64 for venting the clean, filtered air into the conduit 12 for return to the plant environment.

Until the present disclosure, flat planar side panels have been used in air filter assemblies such as described herein. However, it has been found that in certain conventional systems, an to attempt to operate these types of dust collectors at an increased airflow results in increased air velocities, which in turn results in a reduction of filter life. An increased airflow, for example, 8315 cubic feet per minute (cfm) (about 233 m^3/min) or greater, leads to high cabinet air/dust velocity which can abrade holes in the filter cartridges. The high cabinet air/dust velocity may also inhibit the drop-out of the dust particles into the collection hopper. This results in the filters being plugged and a loss in total dust collection airflow. The air filter assembly of the present disclosure overcomes these problems.

Referring now to Figures 6-7, one embodiment of a non-cylindrical filter element 32 will be explained in detail. It has been found that using non-cylindrical filter elements increases the air volume potential by decreasing the air flow velocity.

Filter element 32 has a non-cylindrical sleeve of filtration media 35, preferably pleated, extending from proximal end cap 82 to a distal end cap 44. Typically, proximal end cap 82 is annular, providing for access to the clean air or filtered air chamber. Distal end cap 44 may be annular or continuous, depending on the embodiment. In the context of this disclosure, an "annular end cap" is one where the end cap is ring-like and allows access to the interior of filtration media 35, and a "continuous end cap" is one that extends across the span of filtration media 35 and does not allow access to the interior of filtration media 35. Generally for two stacked filter elements 32, distal end cap 44 will be annular for the first of the stacked filter elements 32 and distal end 82 will be a continuous cap with a central aperture for passing a bolt therethrough for the second elements. A central aperture (minimal in size) may be included in a continuous end cap to allow passage of a bolt or other fastener therethrough so as to provide attachment of the filter element 32 to stepped tube sheet 28, however any aperture is tightly sealed by the fastener.

The length of filter element 32, shown as "x" in Figure 6, generally taken from the outermost end of proximal end cap 82 to the outermost end of distal end cap 44 is at least about 45.7 cm (18 inches), less than about 122 cm (48 inches), typically about 55.9-76.2 cm (22-30 inches), often about 61.0-71.1 cm (24-28 inches), and preferably about 66.0 cm (26 inches), although longer and shorter filter elements could be used. Additionally, multiple filter elements 32, for example, two, three, or more filter elements 32, may be axially stacked to provide more filtration area.

Because filter element 32 is non-cylindrical, filtration media 35 and each end cap 82, 44 are also non-cylindrical; each end cap has a long axis 75 and a short axis 76, when taken perpendicular to the filtration media 35. Figure 7 illustrates proximal end cap 82 with long axis 75 and short axis 76.

The aspect ratio, that is, the ratio between the short axis 76 of the end cap and the long axis 75 of the end cap, is typically at least about 0.5, less than 1.0, and is preferably about 0.7 to 0.9. In some systems, an aspect ratio of about 0.80 is preferred. In some systems, an aspect ratio of about 0.80 is preferred. It has been found that the lower the aspect ratio, the lower the air velocity as the air flows through the dirty air chamber 22 and around and through the filter elements 32. This results in less damage to the filter elements 32 and longer element life. Also, an aspect ratio of about 0.8 for a non-cylindrical filter element provides an increase of airflow by about 25% over that of a cylindrical filter element, while keeping the cabinet velocities the same. However, as the aspect ratio for non-cylindrical filter elements decreases (i.e., the short axis 76 decreases in relation to the long axis 75), it becomes difficult to pulse clean air backwards through the elements 32 to loosen compacted particulates, due to the narrowness of the element through which the air pulse must travel.

The exterior dimension of end cap 82 (and end cap 44), when taken along the long axis 75, is at least about 15 cm, less than about 60 cm, typically is about 27.9-45.7 cm (11-18 inches), and preferably about 33.0-38.1 cm (13-15 inches). The interior dimension of end cap 82 (and optionally of end cap 44), when taken along the long axis 75, is at least about 5 cm, less than 55 cm, typically about 20.3-38.1 cm (8-15 inches), and preferably about 25.4-30.5 cm (10-12 inches). The

exterior dimension of end cap 82 (and end cap 44), when taken along the short axis 76, is at least about 10 cm but less than about 55 cm, typically is about 20.3-38.1 cm (8-15 inches), preferably about 25.4-30.5 cm (10-12 inches). Generally, the interior dimension of the end cap 82 (and optionally of end cap 44), when taken along the short axis 76, is at least about 5 cm, less than about 50 cm, typically is about 12.7-30.5 cm (5-12 inches), and preferably about 17.8-22.9 cm (7-9 inches). The dimensions of the proximal end cap 82 and the distal end cap 44 will usually be the same; that is, typically the filter element 32 will not be tapered, but for some embodiments a taper may in fact be desired.

In a preferred embodiment of a non-cylindrical filter element 32, the exterior dimensions of both end caps 82, 44 are 37.70 cm (14.844 inches) along the long axis 75, and 30.08 cm (11.844 inches) along the short axis 76. If the end cap is annular, the interior dimensions of either end cap 82, 44 are 27.88 cm (10.976 inches) along the long axis 75, and 20.26 cm (7.976 inches) along the short axis 76. The length of the filter element 32 is preferably about 66.0 cm (26 inches). Thus, if two elements 32 were stacked, the overall length of the filter elements 32 would be 132.1 cm (52 inches).). In another preferred embodiment, the exterior dimensions of either end cap 82, 44 are 36.47 cm (14.360 inches) along the long axis 75, and 28.85 cm (11.36 inches) along the short axis 76.

The air filter assembly of the present disclosure is designed to filter particulate from an incoming dirty air stream at a rate greater than conventional air filter assemblies that utilize cylindrical filter elements and planar side paneled housings. One embodiment of the present disclosure provides a method of filtering dirty air to provide clean air. In particular, dirty incoming air, having a particulate contaminant concentration of at least 1 grain per cubic foot of air, is passed through an air filter assembly, preferably having non-cylindrical filter elements. The volume of incoming dirty air is at least 550 cfm (about 15.4 m^3/min), preferably at least 600 cfm (about 16.8 m^3/min), and most preferably at least 625 cfm (about 17.5 m^3/min). The clean air exiting the air filter assembly has a contaminant concentration less than 0.001 grain per cubic foot.

Experimental

Computer modeling was run to compare the shape of side wall panels, i.e., internal verticals stiffeners versus a distended side panels, and cylindrical filters versus non-cylindrical filters. The modeling was done by using Computational Fluid Dynamics (CFD) software commercially available from Fluent, Inc. (of Lebanon, New Hampshire), which is a program commonly used for analyzing laminar and turbulent fluid flow problems. A Hewlett-Packard V-Class computer with 16 microprocessors was used to run the modeling.

CFD predicts flow through a volume (i.e., a domain) by using two equations: the continuity equation, $\rho_1 A_1 v_1 = \rho_2 A_2 v_2 =$ constant, where ρ is the fluid density, A is the cross-sectional area, and v is the fluid velocity; and the momentum conservation equation, $\delta/\delta t\,(\rho u_i) + \delta/\delta x_j\,(\rho u_i u_j) = -\delta p/\delta x_i + \delta\tau_{ij}/\delta x_j + \rho g_i + F_i$, where p is the static pressure, u is the axial velocity, $d\tau_{ij}$ is the stress tensor (function of molecular velocity), ρg_i is the gravitational body force, and F_i is the external body force. CFD also uses the standard k-ε model to predict flow through the domain. The standard k-ε model is a semi-empirical model based on model transport equations for the turbulent energy (k) and its dissipation rate (ε). The model transport equation for k is derived from the exact equation, while the model transport equation for ε is obtained using physical reasoning. In the derivation of the k-ε model for the present system, it was assumed that the flow is fully turbulent, and the effects of molecular viscosity are negligible. Based on the above equations, velocity, pressure and turbulence at any point of domain, flow path, can be predicted.

The various models (i.e., distended side panels and planar side panels, and cylindrical filters and non-cylindrical filters), were created using GAMBIT software package from Fluent, Inc. which is designed for building and meshing models for CFD. Each model utilized 16 filter elements to form eight rows of filter element pairs; each model with 16 filters used 1,457,024 Tet/Hybrid cells. All models were programmed with a Standard ABR (abrasion resistant) inlet with 18 inch (about 45.7 cm) diameter inlet duct and 37 inches by 20 inches (about 94 cm by

51 cm) rectangular outlet. After exporting models from GAMBIT to Fluent, the configuration in CFD was set as follows:

Parameter	Cylindrical Filter Elements	Non-Cylindrical Filter Elements
Turbulence Model	k-epsilon (2 eqn)	k-epsilon (2 eqn)
Materials	Air	Air
Inlet Velocity	21.03 m/s	26.3 m/s
Outlet	Pressure Outlet	Pressure Outlet
Filter	Porous-Zone	Porous-Zone
Filter's Viscous Resistance	8.445e+08 $1/m^2$	8.945e+08 $1/m^2$

Discretization	Pressure-Standard	Pressure-Standard
	Momentum-2nd Order	Momentum-2nd Order
	Upwind	Upwind
	Pressure Vel. Coupling-	Pressure Vel. Coupling-
	SIMPLE	SIMPLE
	Turb. Kinetic Energy	Turb. Kinetic Energy-
	1st Order Upwind	1st Order Upwind
	Turb. Dissipat. Rate -	Turb. Dissipat. Rate -
	1st Order Upwind	1st Order Upwind

Residual Monitors	Continuity = 0.0001	Continuity = 0.0001
	x-velocity = 0.001	x-velocity = 0.001
	y-velocity = 0.001	y-velocity = 0.001
	z-velocity = 0.001	z-velocity = 0.001
	k = 0.001	k = 0.001
	ε = 0.001	ε = 0.001

Two models were created as described above using non-cylindrical filter elements and an airflow of 9145 cfm (about 256 m^3/min). One of these models used a housing having flat side panels and the other model used distended side panels. The distended side panel was dimensioned, as per Figure 5B, with "a'" at 10.4 cm (4.1 inches), "c" at 16.7 cm (6.6 inches), "d" at 8.6 cm (3.4 inches), "e" at 6.4 cm (2.5 inches), "f" at 66.0 cm (26.0 inches), and angle "α" at 14.2 degrees.

The model showed that combination of the non-cylindrical filter elements within a housing having the distended side panel provided an air velocity of about 700 ft/minute, which was a reduction of approximately 30% when

compared to non-cylindrical filters within a housing having vertical internal stiffeners.

A third model was created to compare non-cylindrical filter elements to cylindrical filter elements in a housing having flat side panels. The model with the cylindrical filter elements had a total system air flow of 7315 cfm (about 205 m^3/min) and the non-cylindrical element system had a total system airflow of 9145 cfm (about 256 m^3/min). The results of the modeling showed that similar velocity fields exist within the dirty air chamber for the air filter assembly with cylindrical filter elements and for the air filter assembly with non-cylindrical filter elements. The volume of air passing through the model with the non-cylindrical filter elements was 25% more than the model employing cylindrical filter elements.

It is to be understood, however, that even though numerous characteristics and advantages of the present disclosure have been set forth in the foregoing description, together with details of the structure and function of the disclosure, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts within the principles of the disclosure to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

We claim:

1. An air filter assembly comprising

(a) a housing including an air inlet, an air outlet, a spacer wall separating the housing into a filtering chamber and a clean air chamber;

(i) the housing comprising a plurality of side walls forming the filtering chamber, at least one of the side walls having a non-straight wall including: a first wall portion and a second wall portion with a first angle therebetween;

(ii) the air inlet providing a dirty air volume to the air filter assembly, the dirty air volume having an air flow direction; and

(b) a filter construction positioned in air flow communication with an air flow aperture in the spacer wall; the filter construction including an extension of filter media defining a filter construction inner clean air chamber; the filter construction extending into the filtering chamber.

2. The air filter assembly according to claim 1, wherein the angle is 5 to 20 degrees.

3. The air filter assembly according to claim 2, wherein the angle is about 14 degrees.

4. The air filter assembly according to any of claims 1 through 3, wherein the filter construction is a cylindrical filter construction.

5. The air filter assembly according to any of claims 1 through 3, wherein the filter construction is a non-cylindrical filter construction.

6. The air filter assembly according to claim 5, wherein the non-cylindrical filter construction has a cross-sectional area when taken parallel to the first air flow aperture;

(i) the non-cylindrical filter construction having a long axis perpendicular to a short axis within the cross-sectional area; and

(ii) the non-cylindrical filter construction having a width along the long axis and a width along the short axis, the long axis width being greater than the short axis width, and the long axis positioned parallel to the air flow direction.

7. An air filter assembly comprising:

(a) a housing including an air inlet, an air outlet, a spacer wall separating the housing into a filtering chamber and a clean air chamber;

(i) the air inlet providing a dirty air volume to the air filter assembly, the dirty air volume having an air flow direction;

(b) a filter construction positioned in air flow communication with an air flow aperture in the spacer wall; the filter construction including an extension of filter media disposed between proximal end cap and distal end cap; the filter media, proximal and distal end caps defining a filter construction inner clean air chamber;

(i) the filter construction being oriented within the filter inner clean air chamber in air flow communication with the spacer wall first air flow aperture;

(ii) the filter construction having a cross-sectional area, when taken parallel to the air flow aperture, the cross-sectional area having a long axis perpendicular to a short axis; and

(iii) the filter construction having a width along the long axis and a width along the short axis, the long axis width being greater than the short axis width and the long axis positioned parallel to the air flow direction.

8. The air filter assembly according to any of claim 6 and 7, wherein the ratio of the long axis to the short axis is in the range of about 2:1 to 1.1:1.

9. The air filter assembly according to claim 8, wherein the ratio of the short axis to the long axis is about 0.8.

10. The air filter assembly according to any of claims 7 through 9, wherein the housing comprises at least one planar side wall forming the filtering chamber.

11. The air filter assembly according to any of claims 7 through 9, wherein the housing comprises a plurality of side walls forming the filtering chamber, at least one of the side walls having a non-straight wall including: a first wall portion and a second wall portion with a first angle therebetween;

12. The air filter assembly according to any of claim 1 through 11 further comprising a second filter construction positioned in air flow communication with an air flow aperture in the spacer wall; the filter construction including an extension of filter media defining a filter construction inner clean air chamber; the filter construction extending into the filtering chamber.

13. The air filter assembly according to any of claims 1 through 5 and 11, further comprising a second side wall opposite the at least one side wall, the second side wall having a first wall portion and a second wall portion with a second angle therebetween, the filter construction and the second filter construction positioned parallel to one another between the at least one side wall and the second side wall.

14. The air filter assembly according to claim 13, further comprising a third wall portion, the second wall portion and the third wall portion having therebetween a second angle.

15. The air filter assembly according to claim 14, wherein:

(i) the first wall portion is parallel to the extension of filter media;

(ii) the second wall portion is positioned to the first wall portion at an angle of about 5 to 20 degrees; and

(iii) the third wall portion is parallel to the extension of filter media.

16. The air filter assembly according to claim 14, further comprising a first minimum distance between the first wall portion and the extension of filter media and a second minimum distance between the third wall portion and the extension of filter media, the second minimum distance greater than the first greater distance.

17. The air filter assembly according to claim 16, wherein the first minimum distance is about 10 cm and the second minimum distance is about 17 cm.

18. The air filter assembly according to claim 17, wherein the first minimum distance is about 5 cm less than the second minimum distance.

19. The air filter assembly according to any of claims 1 through 28 further comprising a Venturi element mounted in the spacer wall first air flow aperture and positioned to project into the first filter construction inner clean air chamber.

20. A method of cleaning air, comprising:

(a) inputting dirty air into a filter assembly according to any of claims 1 through 19;

(b) filtering the dirty air through the filter construction; and

(c) receiving clean air out from the clean air chamber of the filter assembly via the air outlet.

21. The method according to claim 20, wherein the step of inputting dirty air into a filter assembly comprises:

(a) inputting dirty air into the filter assembly with a portion of the dirty air volume passing by the non-straight wall.

22. The method according to claim 20, wherein the step of receiving clean air out from the clean air chamber comprises:

(a) receiving clean air out from the clean air chamber with a portion of the clean air passing by the non-straight wall.

23. The method of filtering dirty air according to claim 20, the step of providing a housing including a filtering chamber, the filtering chamber having a volume of no greater than about 6 m^3 comprising providing a housing including a filtering chamber, the filtering chamber having a volume no greater than about 176 cubic feet.

FIG. 1A

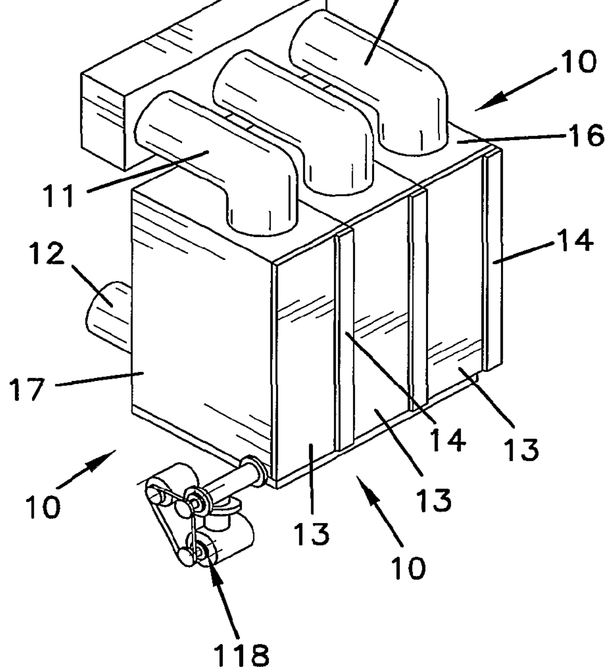


FIG. 3A

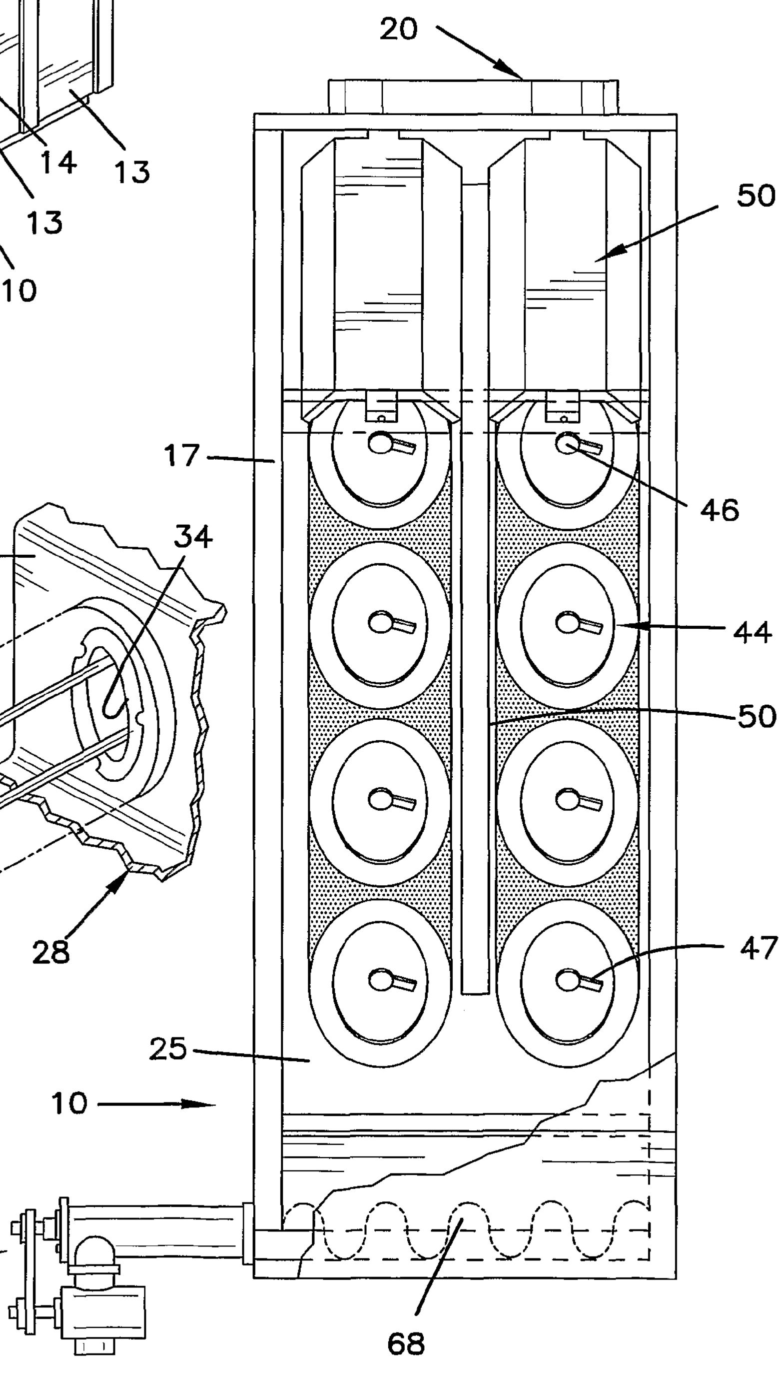


FIG. 4

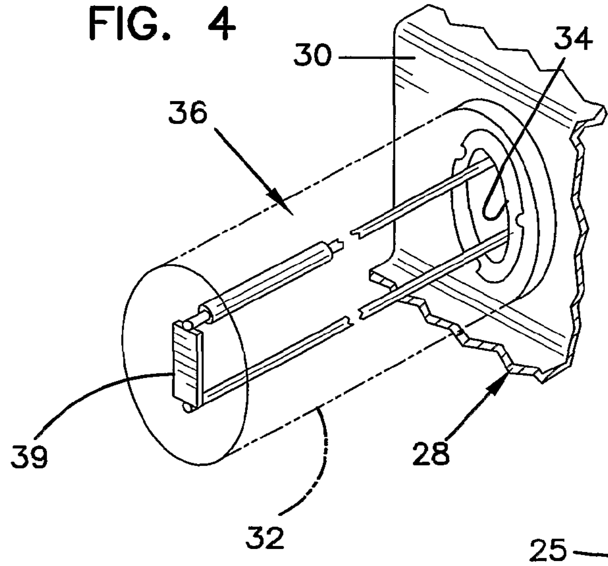
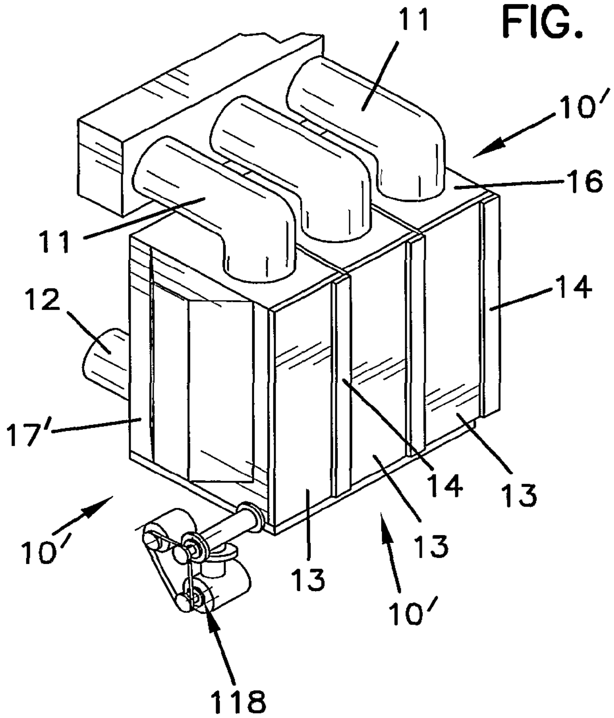


FIG. 1B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17′
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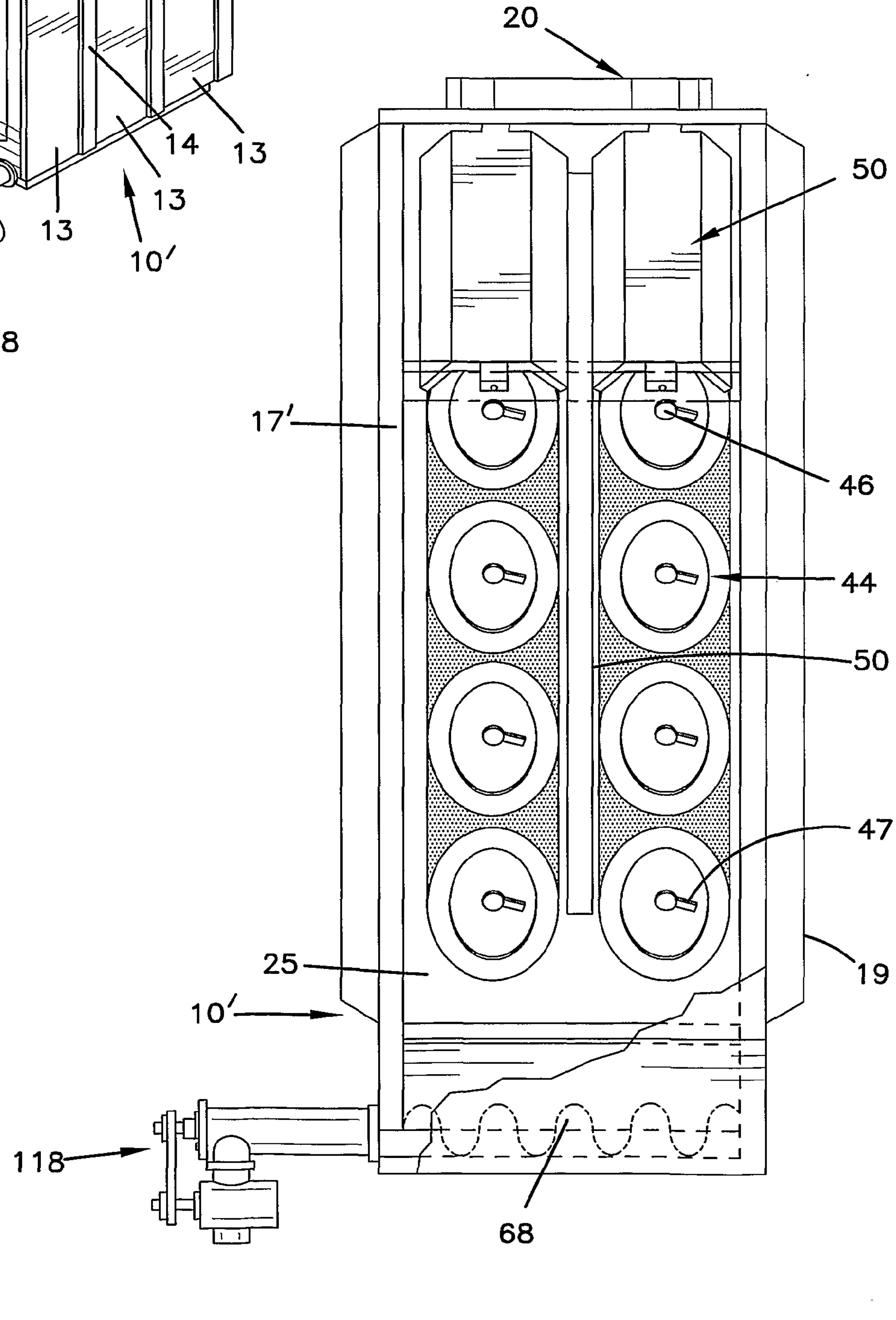
13
10′
118

FIG. 3B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50
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44
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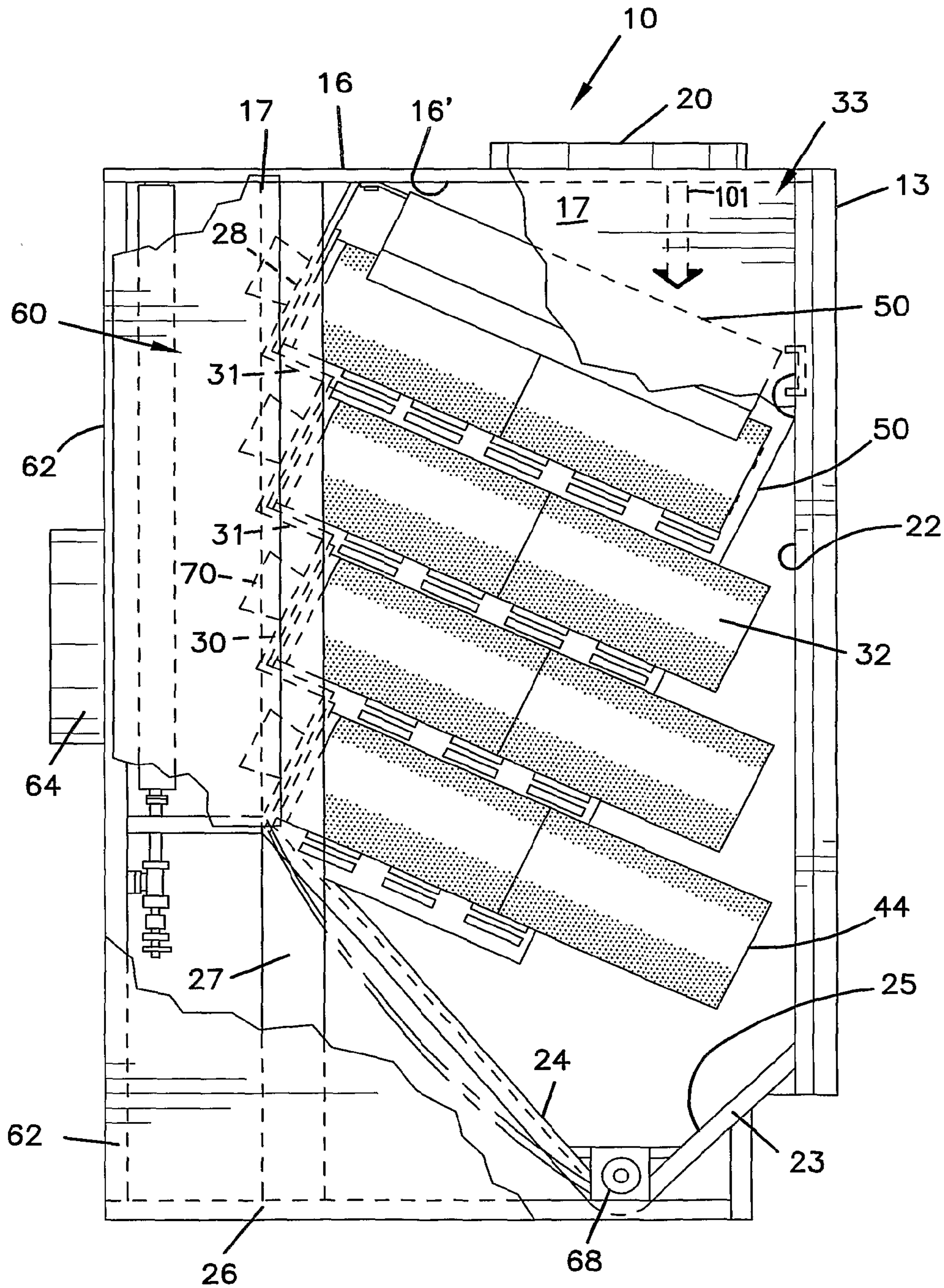
10′
118
68

FIG. 2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26

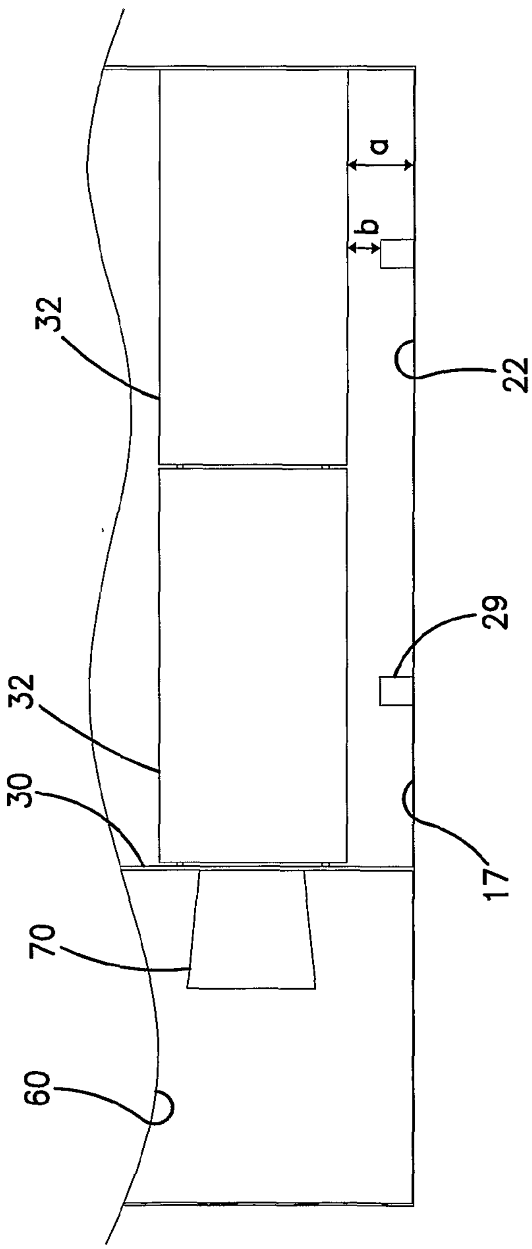


FIG. 5A

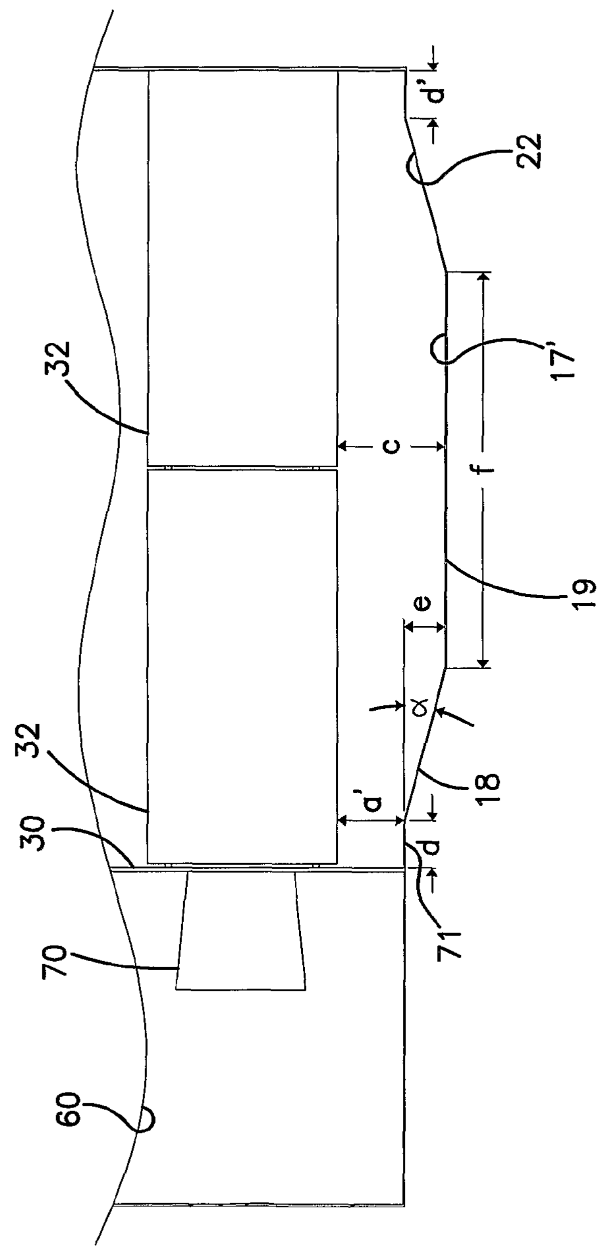


FIG. 5B

FIG. 6

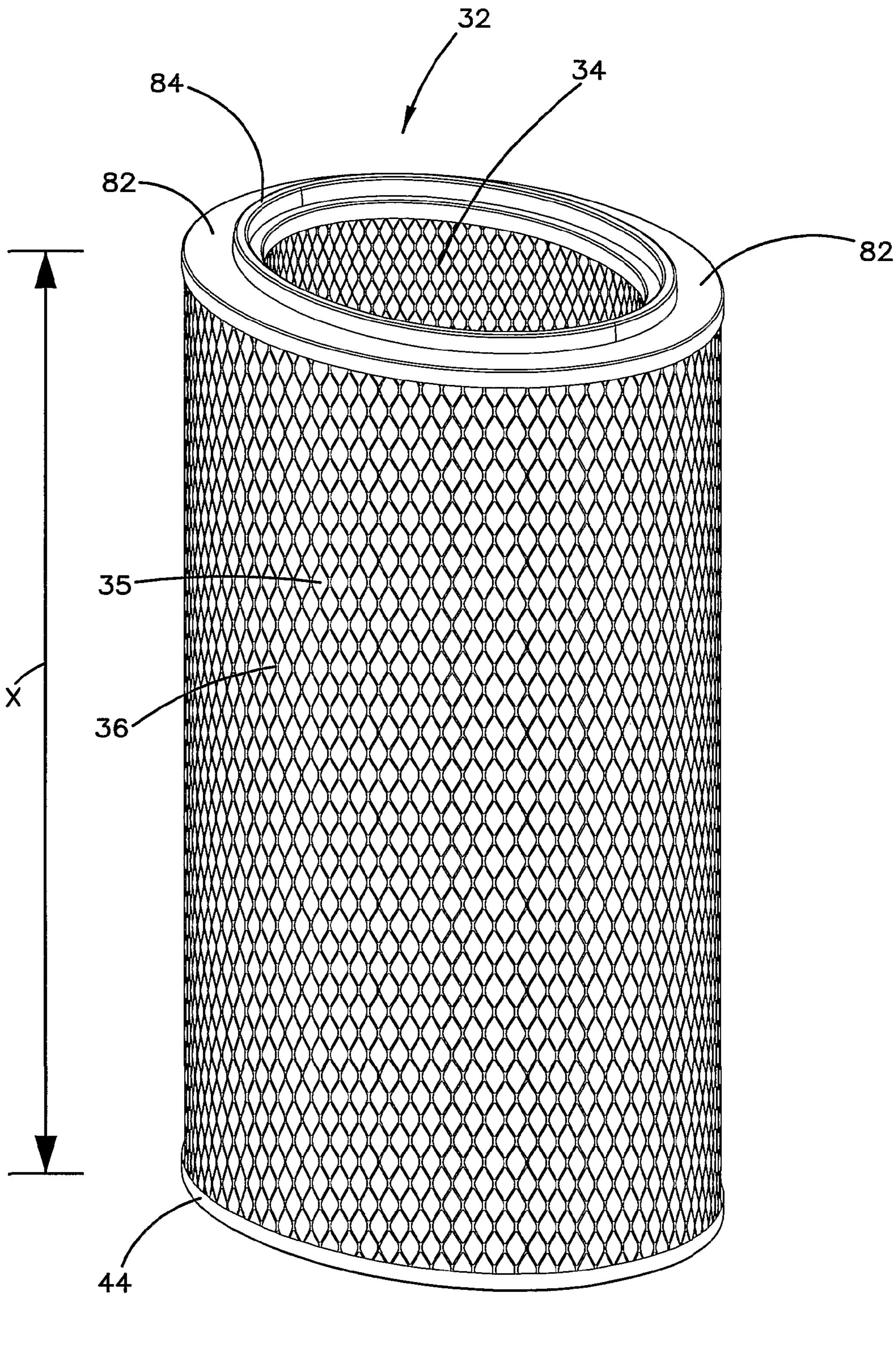
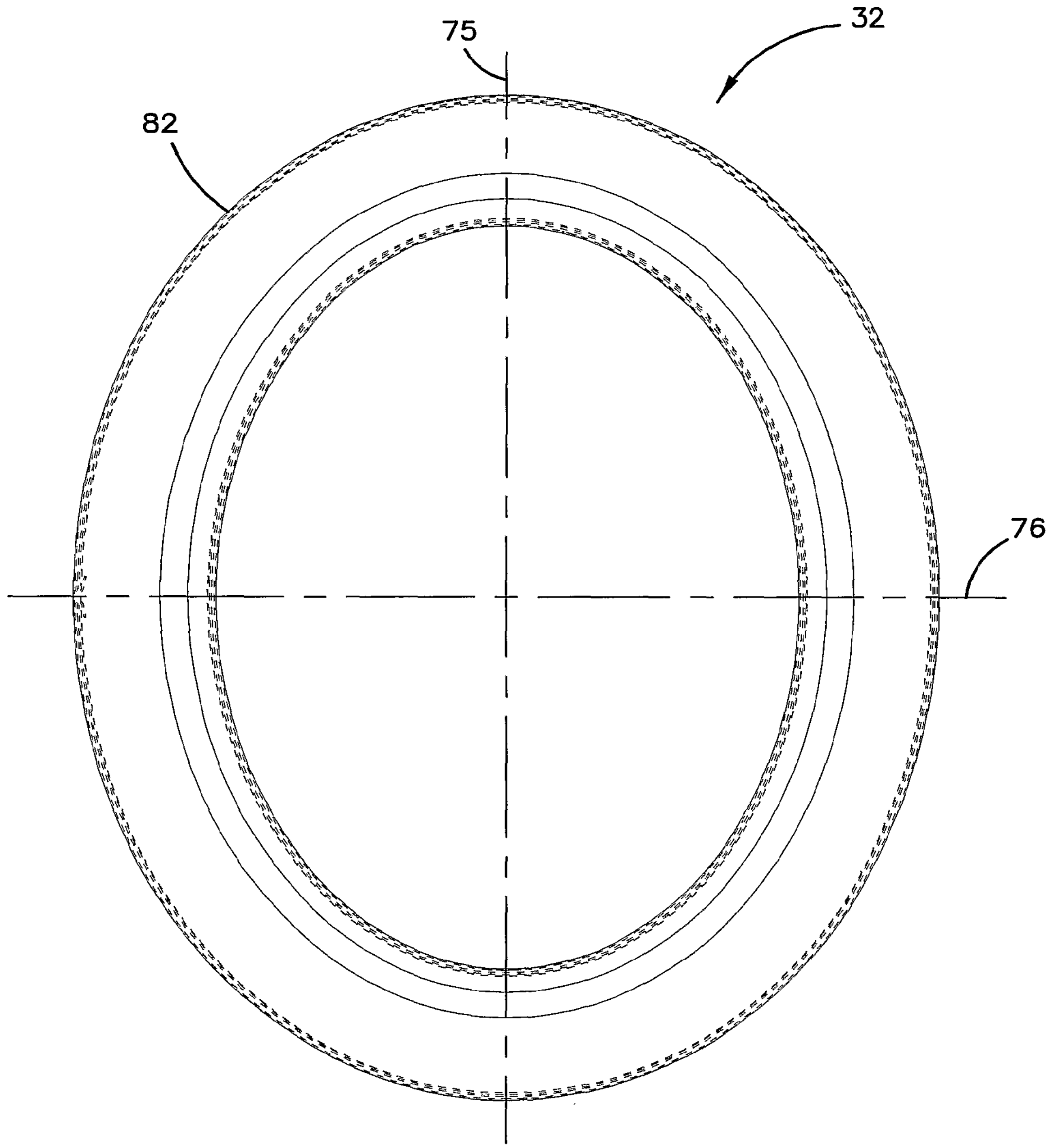


FIG. 7



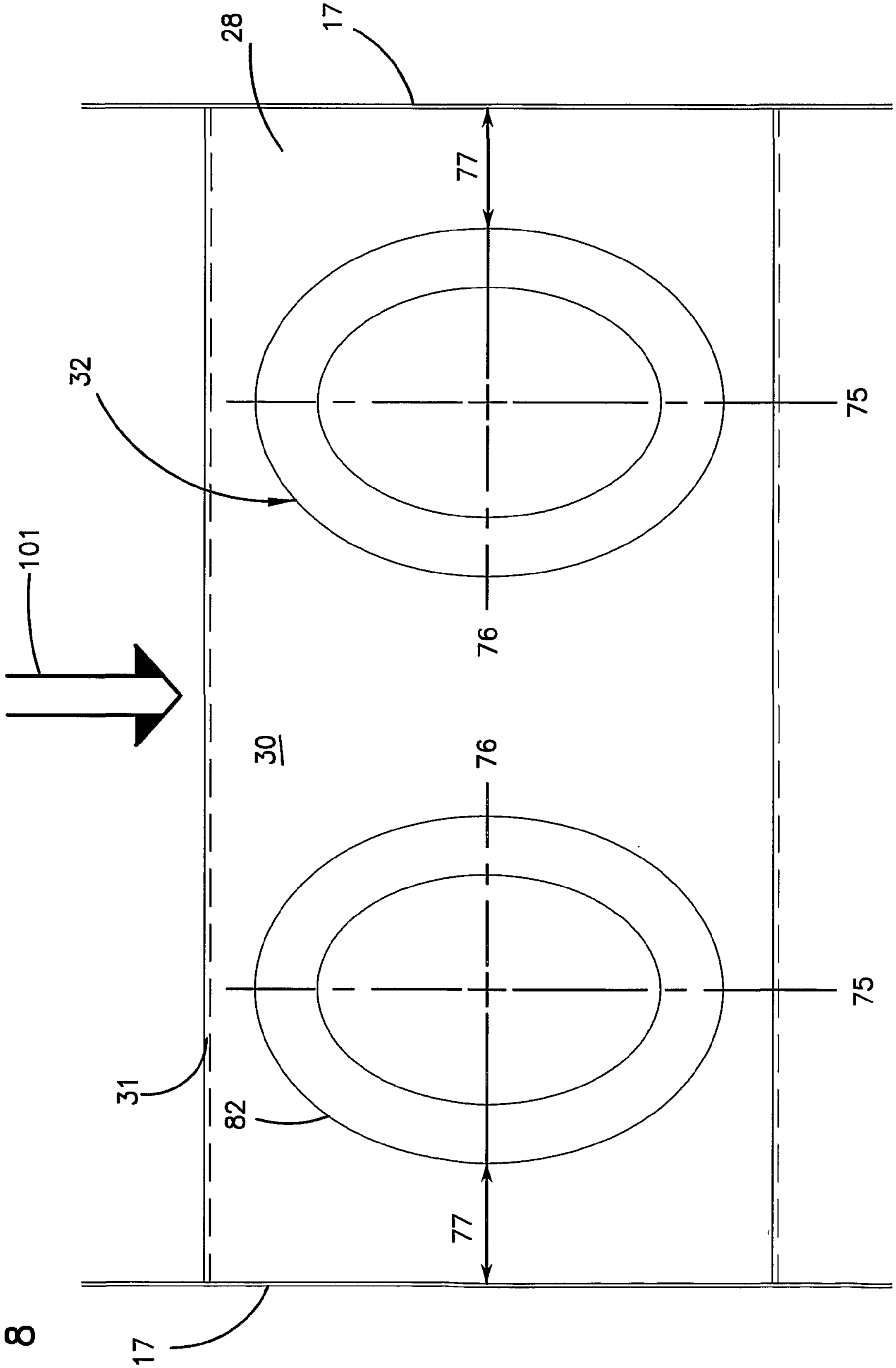


FIG. 8

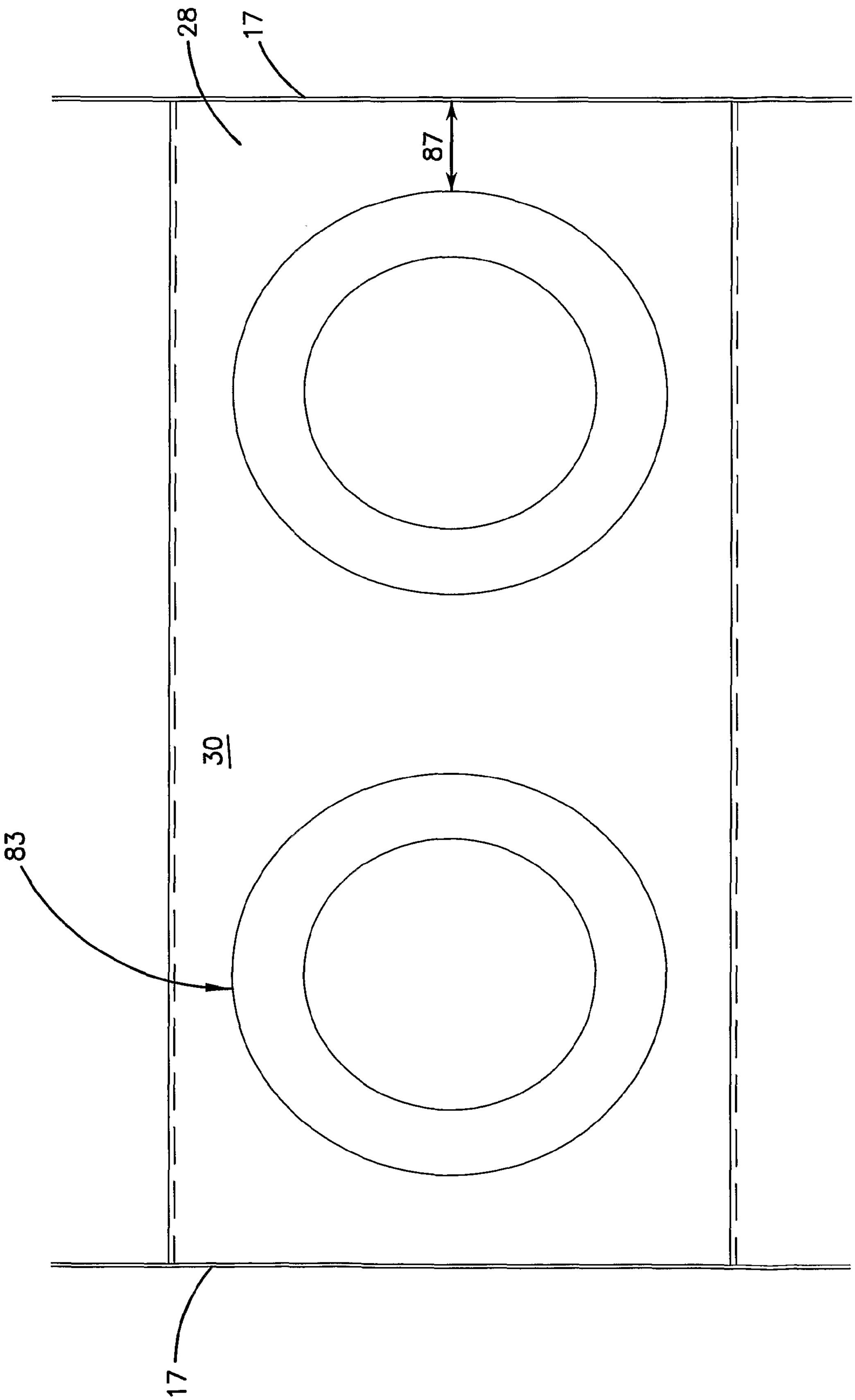


FIG. 9